Ministry of Transportation
Ontario

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A REVIEW OF MTO CONCRETE COMPRESSIVE STRENGTH DATA FOR 1990

MATERIALS INFORMATION

ENGINEERING MATERIALS OFFICE

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A REVIEW OF MTO CONCRETE COMPRESSIVE STRENGTH DATA FOR 1990

BY

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ENGINEERING MATERIALS OFFICE
CONCRETE SECTION

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INTRODUCTION

Most concrete placed on Ministry contracts must meet the requirements of OPSS 1350 in the Ontario Provincial Standard Specifications. One of the requirements of acceptance is based on the results of 28-day compressive strength tests as specified in Section 1350.08.05 of the specifications. Copies of the 28-day compressive strength test results from each region are forwarded to the Concrete Section of the Engineering Materials Office in Downsview. The results are reviewed and are used to provide contract, regional and provincial summaries.

This report provides a summary and review of 28-day compressive strength test results. The summary includes test results of all concrete classes from 20 MPa to 40 MPa. Not included in the report are results on concrete placed on maintenance and municipal contracts or tremie concrete. Only the test results from concrete placed in 1990 are included in the report.

An End Result Specification for Concrete has been used on selected contracts. Under this specification, concrete is accepted based on a statistical analysis of the mean and standard deviation of all acceptance cylinders in a particular lot.

RESULTS

A test is defined as the average of two standard 150 mm x 300 mm cylinders as stated in OPSS 1350. For this report the terms "pass" and "fail" have been used. The "pass" term indicates that the results of a single 28-day compressive test (average of 2 standard cylinders) is greater than or equal to the specified strength. The "fail" term indicates that the result of a single 28-day compressive strength test is less than the specified strength. Table A shows the total number of tests performed in each of the five regions as well as the percentage of the tests that passed and failed. In Table B the tests in each region are broken down by concrete class including concrete containing slag cement and latex modified concrete.

Figures 1 - 12 provide a graphical summary of test results by concrete class and type. The figures show the mean and the standard deviation of all test results by contract for each concrete class in the five regions. Actual contract numbers in each region have been replaced with a series of numbers beginning at 1. Contracts that contain less than two results for a given concrete class are not shown in these figures. Appendix A contains the statistics for all test results throughout the Province in tabular form including a list of contracts under the performance specifications.

The summary of test results for 20 MPa class concrete containing no slag cement are present in Figure 1. In general, the results show that there were no difficulties in meeting the strength requirements by any of the regions.

TABLE A **SUMMARY OF TESTS BY REGION**

REGION	TOTAL NUMBER OF TESTS (Including Performance Specification)	% PASS	% FAIL
CENTRAL	2301	96.1	3.9
SOUTHWESTERN	766	96.9	3.1
EASTERN	701	97.3	2.7
NORTHWESTERN	434	95.4	4.6
NORTHERN	287	85.7	14.3
ALL REGIONS	3132	95.0	5.0

REGION	NUMBER OF TESTS (Under Performance Specification)	% PASS	% FAIL
CENTRAL	893	97.1	2.9
SOUTHWESTERN	329	98.8	1.2
EASTERN	-	-	-
NORTHWESTERN	42	96.2	4.8
NORTHERN	93	96.7	4.3
ALL REGIONS	1357	97.3	2.7

TABLE B SUMMARY OF TESTS BY REGION (NON-SLAG CEMENT, SLAG CEMENT, LATEX MODIFIED CONCRETE)

REGION	20 MPa		20 MPa SLAG		25 MPa		25 MPa SLAG		30 MPa	
	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS
CENTRAL REGION	28	100	99	100	27	67	84	100	117	82.9
SOUTHWESTERN REGION			12	100	23	91.3	61	100	110	96.4
EASTERN REGION	97	100			65	100	73	100	230	97.0
NORTHWESTERN REGION	25	100			70	97.1			274	94.2
NORTHERN REGION	8	100	1	100	57	96.5			200	85.0
ALL REGIONS	158	100	112	100	242	93.8	218	100	931	90.5

REGION	30 MPa SLAG		30 MPa LATEX		35 MPa		35 MPa SLAG		40 MPa SLAG	
	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS	#TESTS	% PASS
CENTRAL REGION	1364	96.5	125	97.6			436	98.2	21	95.2
SOUTHWESTERN REGION	517	96.5					43	100		
EASTERN REGION	236	94.9								
NORTHWESTERN REGION	65	96.9								
NORTHERN REGION	7	57.1			12	58.3	2	50.0		
ALL REGIONS	2189	96.2	125	97.6	12	58.3	481	98.1	21	95.2

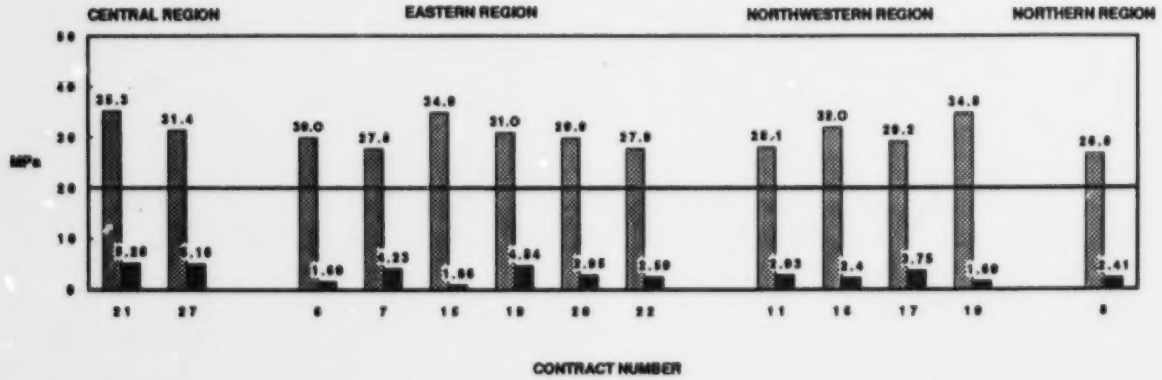


FIGURE 1: SUMMARY OF TESTS BY CONTRACT - 20 MPa NON-SLAG CEMENT

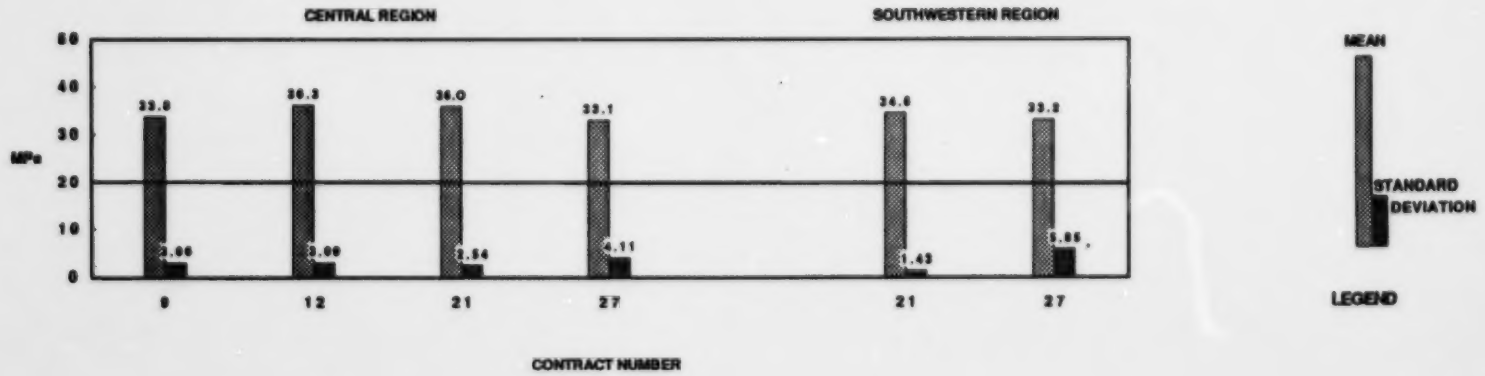


FIGURE 2: SUMMARY OF TESTS BY CONTRACT - 20 MPa SLAG CEMENT

Figure 2 presents the test results for 20 MPa class concrete containing slag cement. Good compressive strengths were achieved with this class of concrete.

Figure 3 contains the summary of test results for 25 MPa class concrete containing no slag cement. While no difficulties were encountered by Eastern Region, 33 per cent of 27 tests failed to meet the compressive strength requirement in Central Region. Southwestern, Northwestern and Northern Regions each had 2 failures out of 23, 70 and 57 tests respectively. No problems are evident in 25 MPa class concrete containing slag cement as shown in Figure 4.

Figure 5 summarizes the test results for 30 MPa class concrete containing no slag cement. All regions experienced difficulties with this class of concrete. Out of 814 tests, 9.5 per cent failed to meet the required compressive strength.

The summary of the test results for 30 MPa class concrete containing slag cement are present in Figure 6. The results for this class of concrete containing slag cement are generally more favourable than this class of concrete containing no slag cement. Out of 2,189 tests, 96.2 per cent met the required compressive strength results.

Figure 7 presents the test results for 30 MPa latex modified concrete. This type of concrete was used only in Central Region. Minor problems were encountered in achieving acceptable compressive strength with this class of concrete.

Figure 8 contains the summary of results of 35 MPa class concrete, both non-slag and slag mixes. The 35 MPa class concrete containing no slag cement was used only by Northern Region. Out of 12 tests, 41.7 per cent failed to meet the required compressive strength. No problems were encountered by Southwestern Region with the 35 MPa class concrete containing slag cement. Central Region had 8 test failures out of 436 tests while Northern Region had 1 test failure out of 2 tests.

Minor problems were encountered in achieving acceptable compressive strengths by Central Region with the 40 MPa class concrete containing slag cement as shown in Figure 9.

A graphical representation for contracts which were under the concrete performance specification are shown in Figures 10, 11 and 12. All results for a class of concrete were combined for each contract irrespective of the actual number of lots of that type. Mean strengths for the 30 MPa concrete ranged from 34.5 to 43.1 MPa and the standard deviation ranged from 1.2 to 6.5 MPa. Mean strengths for the 35 MPa concrete ranged from 42.0 to 48.2 MPa and the standard deviation ranged from 2.7 to .1 MPa.

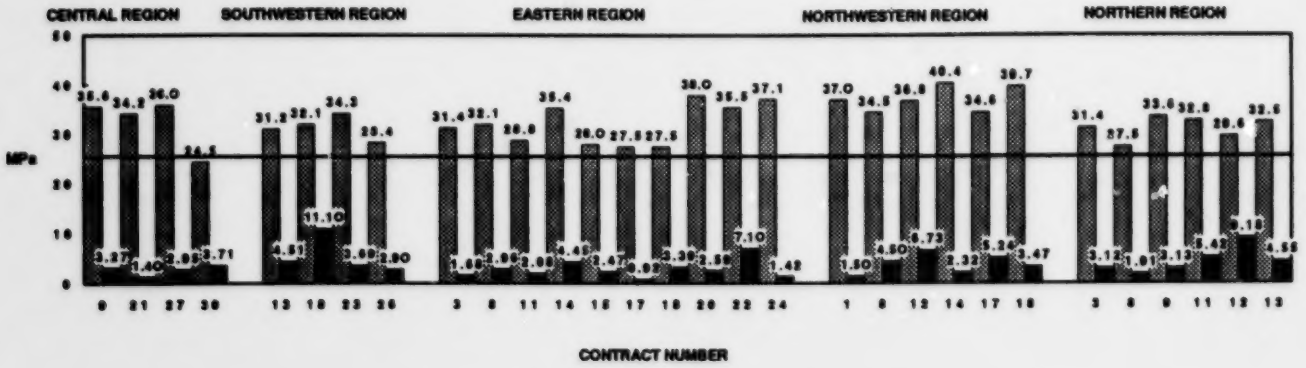


FIGURE 3: SUMMARY OF TESTS BY CONTRACT - 25 MPa NON-SLAG CEMENT

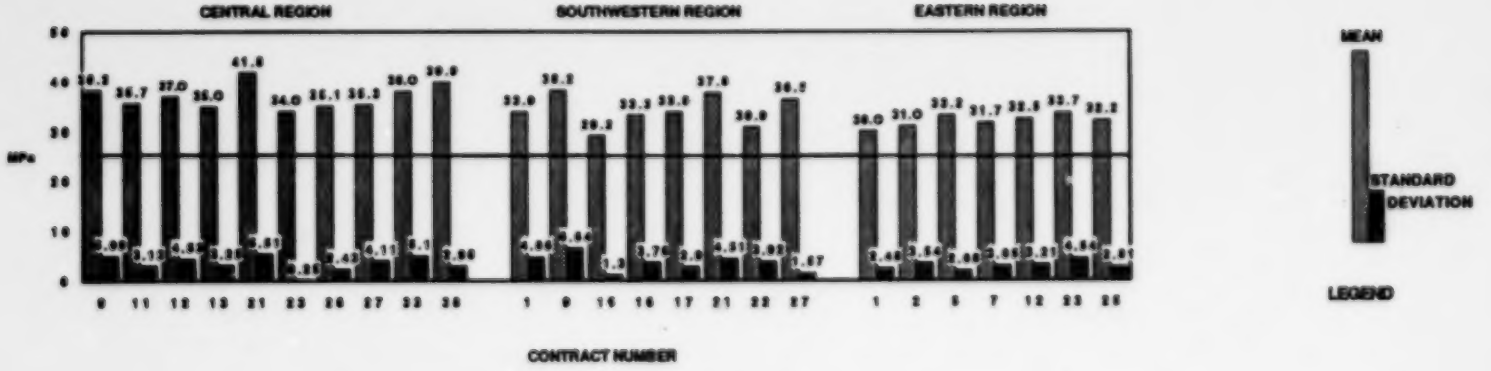


FIGURE 4: SUMMARY OF TESTS BY CONTRACT - 25 MPa SLAG CEMENT

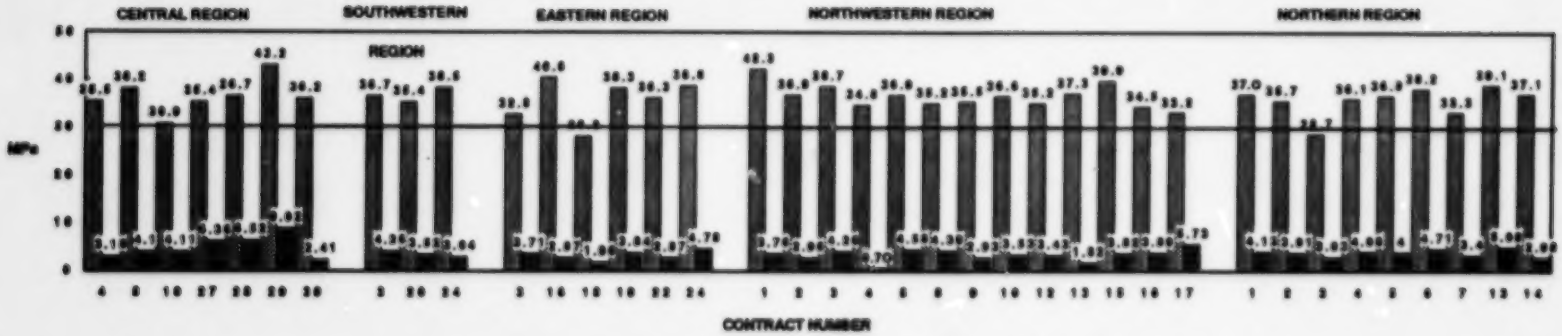


FIGURE 5: SUMMARY OF TESTS BY CONTRACT - 30 MPa NON-SLAG CEMENT

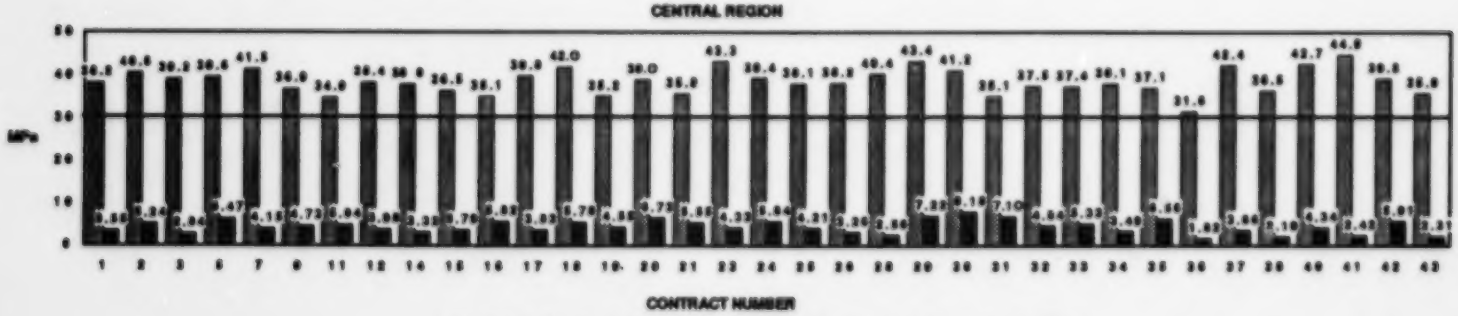


FIGURE 6: SUMMARY OF TESTS BY CONTRACT - 30 MPa SLAG CEMENT

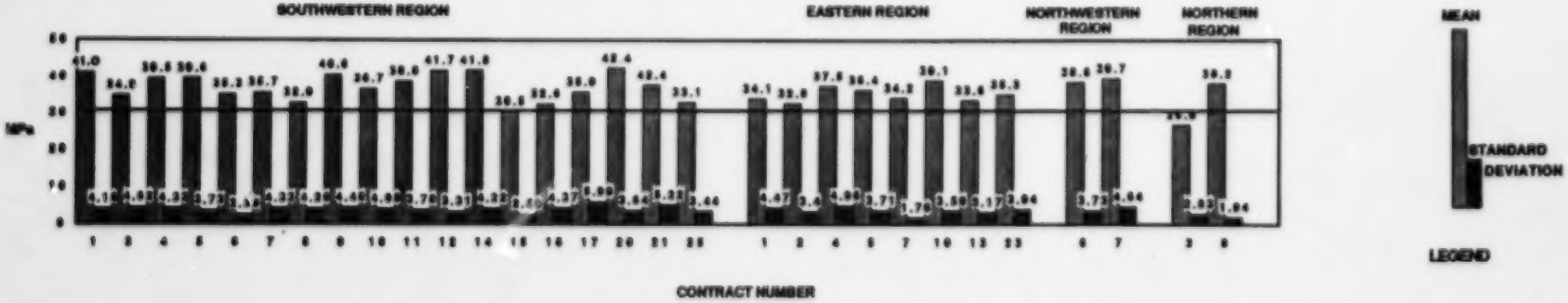


FIGURE 5: SUMMARY OF TESTS BY CONTRACT - 30 MPa SLAG CEMENT

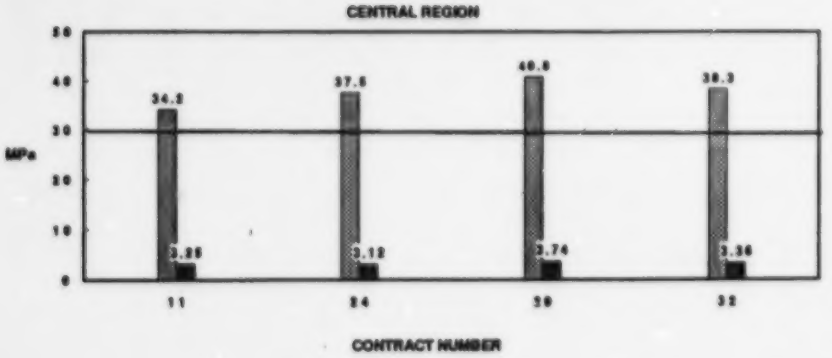


FIGURE 7: SUMMARY OF TESTS BY CONTRACT - 30 MPa LATEX MODIFIED CONCRETE

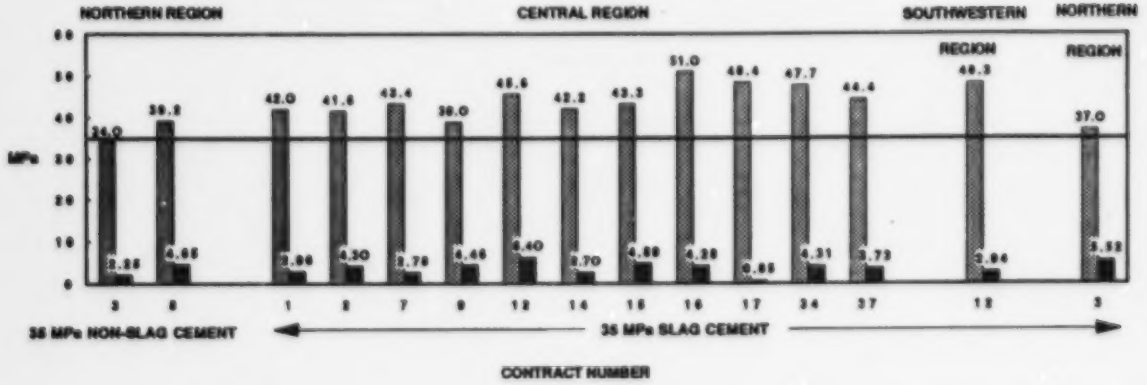


FIGURE 8: SUMMARY OF TESTS BY CONTRACT - 35 MPa NON-SLAG & SLAG CEMENT

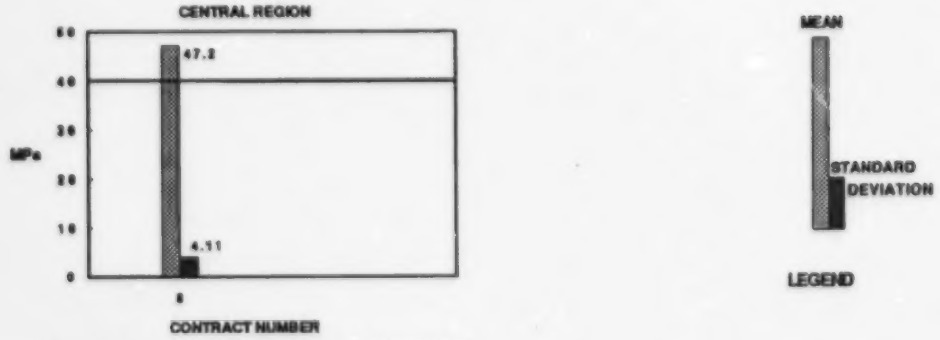
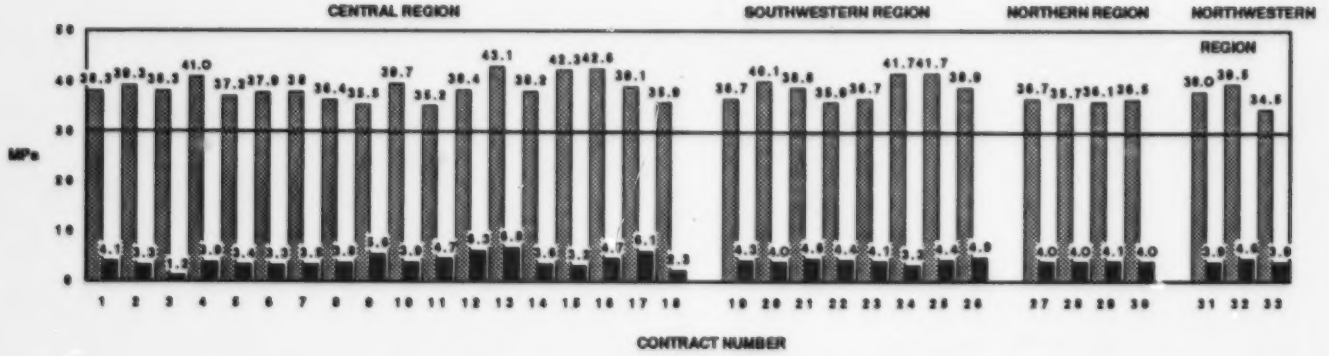


FIGURE 9: SUMMARY OF TESTS BY CONTRACT - 40 MPa SLAG CEMENT



FIGUR 10: SUMMARY OF TESTS BY CONTRACT UNDER THE PERFORMANCE SPECIFICATION (30 MPa CONCRETE)

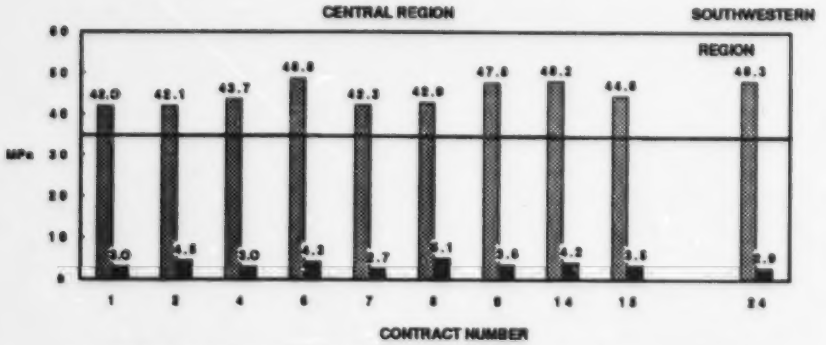


FIGURE 11: SUMMARY OF TESTS BY CONTRACT UNDER THE PERFORMANCE SPECIFICATION (35 MPa CONCRETE)

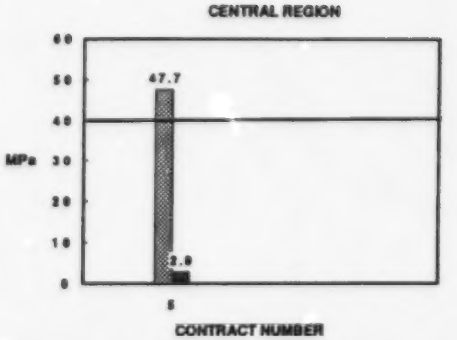


FIGURE 12: SUMMARY OF TESTS BY CONTRACT UNDER THE PERFORMANCE SPECIFICATION (40 MPa CONCRETE)

SUMMARY

1) Good compressive strengths were achieved with the 20 MPa class concrete with or without slag cement and 25 MPa class concrete with slag cement.

2) Eastern Region had no difficulties with the 25 MPa class concrete without slag cement. Minor problems were encountered by Southwestern, Northwestern and Northern Regions. Difficulties were encountered by Central Region with this type of concrete.

3) Low compressive strengths were most evident in 30 MPa class concrete with or without slag cement in all regions.

4) Minor difficulties were encountered by Central Region with the latex modified concrete and 40 MPa class concrete with slag cement.

5) Problems were encountered in Northern Region with the 35 MPa class concrete containing no slag cement. In Southwestern Region good compressive strengths were achieved with the 35 MPa class concrete containing slag cement. Central and Northern Regions experienced low compressive strengths in 35 MPa class concrete containing slag cement.

6) 3,132 tests were carried out in 1990 of which 95.7 per cent were greater or equal to the required strength. Under the performance specification, 97.3 per cent out of 1,357 tests met the required strength.

APPENDIX A

Summary of 28-day Compressive Test Results

CENTRAL REGION

CON-TRACT	20 MPa			20 MPa SLAG			25 MPa			25 MPa SLAG			30MPa			30 MPa SLAG			30 MPa LATEX MOD.			35 MPa SLAG			40 MPa SLAG		
	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	# TESTS	MEAN	ST.DEV.	#TESTS	MEAN	ST. DEV.	#TESTS	MEAN	ST. DEV.
1																15	38.2	3.55				47	42.0	2.96			
2																109	40.8	5.24				29	41.8	4.30			
3																18	39.2	2.84									
4													12	35.5	3.18												
5																11	39.6	6.47									
6							1	25.2	-																		
7																34	41.5	4.15				31	43.4	2.78			
8													22	38.2	4.10										21	47.2	4.11
9				47	33.8	3.06	7	35.6	3.27	11	38.2	5.09	1	28.8	-	67	36.9	4.73				18	39.0	4.46			
10													26	30.9	4.11												
11										13	35.7	3.13				48	34.9	5.04	22	34.2	3.25						
12				28	36.3	3.09				6	37.0	4.53				55	38.4	3.98				50	45.6	6.40			
13										14	35.0	3.25															
14																38	38.0	3.32				83	42.2	2.70			
15																37	36.5	3.79				36	43.3	4.89			
16																45	35.1	5.92				6	51.0	4.28			
17																36	39.8	3.83				2	48.4	0.85			
18																9	42.0	5.78									
19																82	35.2	4.55									
20																24	39.0	6.73									
21	17	36.3	5.26	17	36.0	2.54	3	34.2	1.40	4	41.8	5.51				24	35.8	5.55									
22				1	35.6	-				1	39.0	-															
23	1	37.7	-							2	34.0	0.25				25	43.3	4.33									
24																35	39.4	5.84	16	37.5	3.12						
25																27	38.1	4.21									
26										4	35.1	2.43				26	38.2	3.26									
27	9	31.4	5.16	6	33.1	4.11	6	36.0	2.96	7	35.3	4.1	2	35.4	6.36												
28							1	28.3	-				45	36.7	6.52	14	40.4	2.56									
29				1	29.7	-							2	43.2	9.02	230	43.4	7.22	73	40.8	3.74	1	38.5	-			
30																29	41.2	8.18									
31																5	35.1	7.10									
32																30	37.5	4.84	15	38.3	3.36						
33										14	38.0	5.1				21	37.4	5.33									
34										1	42.1	- -				90	38.1	3.49				108	47.7	4.31			
35																16	37.1	6.56									
36																11	31.6	1.82									
37																22	42.4	3.66				27	44.4	3.73			
38										6	39.9	2.96				3	36.5	2.19									
39	1	29.9	-				10	24.5	3.71				7	36.2	2.41												
40																72	42.7	4.34									
41										1	42.2	-				12	44.9	2.42									
42																24	39.3	5.91									
43																18	35.9	2.31									

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

SOUTHWESTERN REGION

CONTRACT NO.	20 MPa SLAG			25 MPa			25 MPa SLAG			30 MPa			30 MPa SLAG			35 MPa SLAG		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1							5	33.9	4.86				49	41.0	4.18			
2										1	28.6	-						
3										20	36.7	4.26	17	34.9	4.62			
4													140	39.5	4.33			
5													12	39.6	3.73			
6													17	35.3	2.59			
7													23	35.7	4.33			
8							1	41.0	-				4	32.9	4.26			
9							4	38.2	6.64				10	40.6	4.48			
10													19	36.7	4.08			
11													60	38.8	3.78			
12													56	41.7	3.31	43	48.3	2.94
13				3	31.2	4.51												
14													15	41.8	4.22			
15							3	29.2	1.30				6	30.5	2.59			
16							10	33.3	3.76				15	32.6	4.37			
17							5	33.9	2.90				18	35.9	5.99			
18				2	32.1	11.10												
19				1	42.5	-												
20										25	35.4	3.52	24	42.4	3.64			
21	7	34.6	1.43				13	37.8	4.51				24	37.7	5.22			
22							17	30.9	3.92									
23				5	34.3	3.69												
24										64	38.5	3.04						
25													8	33.1	3.44			
26				12	28.4	2.90												
27	5	33.2	5.85				3	36.5	1.57									

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

EASTERN REGION

CONTRACT NO.	20 MPa			25 MPa			25 MPa SLAG			30 MPa			30 MPa SLAG		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1							28	30.0	2.48				25	34.1	4.47
2							4	31.0	3.54				4	32.8	3.40
3				11	31.4	1.68				15	32.8	3.71			
4													52	37.5	4.96
5							5	33.2	2.08				30	36.4	3.71
6	8	30.0	1.69												
7	16	27.8	4.23				5	31.7	3.05				6	34.2	1.76
8				20	32.1	2.96									
9				1	32.8	-									
10													61	39.1	3.59
11				4	28.8	20.80									
12							12	32.5	3.21						
13													29	33.6	3.17
14				2	35.4	4.45									
15	2	34.9	1.06	4	28.0	2.47									
16										104	40.6	2.87			
17				2	27.5	0.92				1	32.7	-			
18				2	27.5	3.39				4	28.2	1.96			
19	41	31.0	4.84							54	38.3	3.84			
20	9	29.9	2.95	6	30.0	2.59									
21													1	31.1	-
22	21	27.9	2.59	7	35.5	7.1				9	36.3	2.87			
23							8	33.7	4.54				28	35.3	3.94
24				6	37.1	1.42				43	38.6	4.78			
25							11	32.2	2.81						
	97			65			73			230			236		

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

NORTHWESTERN REGION

CONTRACT NO.	20 MPa			25 MPa			30 MPa			30 MPa SLAG		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1				3	37.0	1.50	17	42.3	3.76			
2							12	36.9	2.96			
3							40	38.7	4.26			
4							5	34.8	0.70			
5							14	36.9	4.58			
6										33	38.6	3.73
7										32	39.7	4.64
8				19	34.5	4.50	19	35.2	4.39			
9							13	35.5	2.93			
10				1	33.6	-	75	36.6	3.53			
11	10	28.1	2.93									
12				12	36.8	6.73	26	35.2	3.43			
13							15	37.3	1.82			
14				3	40.4	2.32						
15							3	39.9	3.82			
16	2	32.0	2.40				8	34.5	3.89			
17	8	29.2	3.75	25	34.6	5.24	27	33.2	5.73			
18				7	39.7	3.47						
19	5	34.8	1.69									

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

NORTHERN REGION

CONTRACT NO.	20 MPa			20 MPa SLAG			25 MPa			30 MPa			30 MPa SLAG			35 MPa			35 MPa SLAG		
	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1										23	37.0	4.13									
2										25	35.7	3.91									
3							6	31.4	3.12	29	28.7	3.03	3	26.9	2.83	6	34.0	2.25	2	37.0	5.52
4										20	36.1	4.08									
5										42	36.8	4.00									
6										16	38.2	4.71									
7							1	29.0	-	35	33.3	3.40									
8	8	26.6	2.41	1	29.0	-	2	27.5	1.91				4	38.2	1.94	6	39.2	4.65			
9							4	33.6	3.13												
10										1	30.9	-									
11							4	32.8	5.42												
12							5	29.6	9.18												
13							35	32.5	4.55												
14										2	39.1	5.09									
										7	37.1	2.98									

SUMMARY OF 28-DAY COMPRESSIVE STRENGTH TEST RESULTS

SUMMARY OF CONTRACTS UNDER THE PERFORMANCE SPECIFICATION

CONTRACT	30 MPa			35 MPa			40 MPa		
NO.	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV	# TESTS	MEAN	ST.DEV
1	10	38.3	4.10	46	42.0	3.0			
2	37	39.3	3.30	13	42.1	4.5			
3	5	38.3	1.20						
4	13	41.0	3.90	24	43.7	3.0			
5	13	37.2	3.40				18	47.7	2.9
6	13	37.9	3.30	29	48.8	4.3			
7	32	38.0	3.50	81	42.3	2.7			
8	38	36.4	3.80	39	42.9	5.1			
9	43	35.5	5.60	3	47.8	3.6			
10	32	39.7	3.90						
11	77	35.2	4.70						
12	18	38.4	6.30						
13	37	43.1	6.80						
14	82	38.2	3.60	86	48.2	4.2			
15	9	42.3	3.20	20	44.6	3.5			
16	33	42.6	4.70						
17	24	39.1	6.10						
18	18	35.9	2.30						
19	20	36.7	4.30						
20	96	40.1	4.00						
21	13	38.8	4.60						
22	20	35.9	4.40						
23	19	36.7	4.10						
24	56	41.7	3.30	43	46.3	2.9			
25	13	41.7	4.40						
26	49	38.9	4.90						
27	22	36.7	4.00						
28	12	35.7	4.00						
29	20	36.1	4.10						
30	39	36.5	4.00						
31	12	38.0	3.90						
32	22	39.5	4.60						
33	8	34.5	3.90						